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ABSTRACT

Four factors have been reported in the literature as being related to spatial test performance. This study investigated the main and interaction effects of sex, handedness, birth order, and experience on three different types of spatial performance; surface development, object rotation, and coordination of viewpoints. A total of 217 undergraduate students served as subjects, and were classified by sex, handedness, birth order, and experience. Spatial performance was measured by administering the Purdue Spatial Visualization Test. Factorial analysis of variance procedures revealed significant main effects for sex, birth order, and experience. No significant interactions were found. The data indicated that: (1) males performed better than females on all three measures of spatial performance; (2) people born neither first nor last in their family performed better than people born first or last on the object rotation subtest; and (3) people who had much experience with activities requiring spatial thinking performed better than people who had few experiences with these activities on the object rotation subtest. (Author/CTM)

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FACTORS AFFECTING SPATIAL TEST PERFORMANCE: SEX, HANDEDNESS, BIRTH ORDER, AND EXPERIENCE

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Abstract

This study examines four factors reported in the literature as being related to spatial test performance. Specifically, the study investigates the main and interaction effects of sex, handedness, birth order, and experience on three different types of spatial performance: surface development, object rotation, and coordination of viewpoints. A total of 217 university students served as subjects. Information collected with two questionnaires was used to classify the subjects by sex, handedness, birth order, and experience. Spatial performance was measured by administering the Purdue Spatial Visualization Test. Factorial analysis of variance procedures revealed significant main effects for sex, ($p < .01$), birth order ($p < .05$), and experience ($p < .01$). No significant interactions were found. The data indicated that (1) males perform better than females on all three measures of spatial performance; (2) people born neither first nor last in their family perform better than people born first or last on the object rotation subtest; and (3) people who have had much experience with activities requiring spatial thinking perform better than people who have had few experiences with these activities on the object rotation subtest.

FACTORS AFFECTING SPATIAL TEST PERFORMANCE: SEX, HANDEDNESS, BIRTH ORDER, AND EXPERIENCE

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The literature is unclear regarding the conditions underlying observed differences in spatial test performance. Most studies conducted in the area address themselves to the differences found between females and males. Sizeable and reliable sex differences in favor of males in spatial test performance have been widely substantiated (Fennema, 1974; Harris, 1976; Maccoby & Jacklin, 1974). Typical explanations for these differences include genetic (Bock & Kolakowski, 1973), hormonal (Petersen, 1973), environmental (Sherman, 1974), and neurological (Harris, 1975). Some recent literature (Allen, 1974; McGlone & Kertesz, 1973; Yen, 1975) suggests that preferred processing style may also help explain sex differences in spatial test performance. All these explanations, although posited for between-sex differences, are for the most part generalizable to within-sex differences. Sex-related differences as well as general individual differences in spatial test performance are likely a result of the complex interaction of the aforementioned factors. Although this interaction notion seems reasonable, there is a dearth of information in the literature regarding its validity.

This study is designed to examine the interaction notion as it relates to four factors that have been found to be related to spatial test performance. These four factors are sex, handedness, birth order, and experience. The importance of sex was noted earlier. Handedness findings are reported by McGee (1976) and Yen (1975). In both studies, right-handers (dextrals) were found to perform better on spatial tests than left-handers (sinistrals). McGee found the difference among females, but not among males. In contrast, Yen found the difference among males only. With regards to birth order, Kinsolving and Bone (1971) and Sherman (1974) reported a significant interaction between sex and birth order. In both studies, the firstborn males were found to perform better than firstborn females. Evidence for the positive effect of selected experiences on spatial test performance is provided in two areas of the literature. First are experiments that have successfully employed instructional treatments to enhance spatial performance (e.g., Blade & Watson, 1955). Second are studies that have found significant relationships between experiential background and spatial performance (e.g., McDaniel, Guay, Ball, & Kolloff, 1978).

Reported effects of factors on spatial performance rarely note the type of spatial processing affected. Most summaries simply state that significant differences were found in spatial ability. It is well documented (Borich &

Bauman, 1972; Price & Eliot, 1975) that so-called spatial tests often require distinctly different processing strategies. There is some evidence (Guay & McDaniel, 1977; Smith, 1964) to suggest that the same factor may have different effects for different types of spatial processing. For example, Guay and McDaniel (1977) found a significant sex effect for two types of spatial tests loaded on imagery movement and no significant sex effect for two types of spatial tests loaded on perceptual discrimination. Similar results for the sex factor are reported by Smith (1964). A search of the literature revealed no studies concerned with investigating the differential effects of handedness, birth order, and experience on different kinds of spatial processing.

For this reason, this study is designed to examine the effects of the four selected factors on three different kinds of spatial test performance: a surface development task, an object rotation task, and a coordination of viewpoints task. The three tasks are subtests within the Purdue Spatial Visualization Test (Guay, 1977). The three tasks require significantly different cognitive processing strategies. In a study by Guay, McDaniel, and Angelo (1978) of over thirty widely-used spatial tests, the rotation subtest was found to be the most gestalt in terms of processing strategy, whereas the development subtest was found to be one of the most analytic in terms of processing strategy. The viewpoints

subtest was found to be somewhat less gestalt than the rotations subtest, but not as analytic as the development subtest. Gestalt processing involves forming and transforming mental visual images of figures as organized wholes. Analytic processing, on the other hand, involves explicit trial-and-error checking of relationships between different parts of a figure. The gestalt and analytic styles of processing are widely accepted (Smith, 1964; Spearman & Jones, 1950) as the two major processing strategies used in solving spatial tasks.

This brief review of the literature suggests that (1) individual differences in spatial performance may be explained by the interaction of several factors; (2) sex, handedness, birth order, and experience are factors related to spatial performance; and (3) the same factor may have differential effects for different spatial tests.

The preceding notions provide the basis for the design of this study. The study involved the analysis of three distinct types of spatial processing collected on a group of students classified by sex, handedness, birth order, and experience. The major objective of the study was to determine whether main and/or interaction effects of sex, handedness, birth order, and experience exist for the three different types of spatial test performance.

Subjects

A total of 217 university undergraduate students served as subjects in this study. All the subjects were volunteers recruited from students enrolled as either art, education, or industrial arts majors at Purdue University. The participants included 55 art majors, 107 education majors, and 55 industrial arts majors. Among the participants were 135 females and 82 males; 186 dextrals and 31 sinistrals; 64 firstborns of two or more children; 61 lastborns of two or more children, 85 who were neither first- nor lastborns; and 7 who were the only child in their family.

Procedure

The subjects were tested for spatial test performance in small group settings (n of 10 to 20) using the new Purdue Spatial Visualization Test (PSVT). The 36-item PSVT includes three 12-item subtests designed to measure different types of spatial visualization: visualization of developments, visualization of rotations, and visualization of views. A sample item from each of the three subtests is presented in Figures 1 through 3.

Figure 1 shows a PSVT Development item. Presented in the item is a development and five three-dimensional objects. The development shows the inside surfaces of a three-dimensional object. The shaded portion of the development indicates the bottom surface of the three-dimensional object.

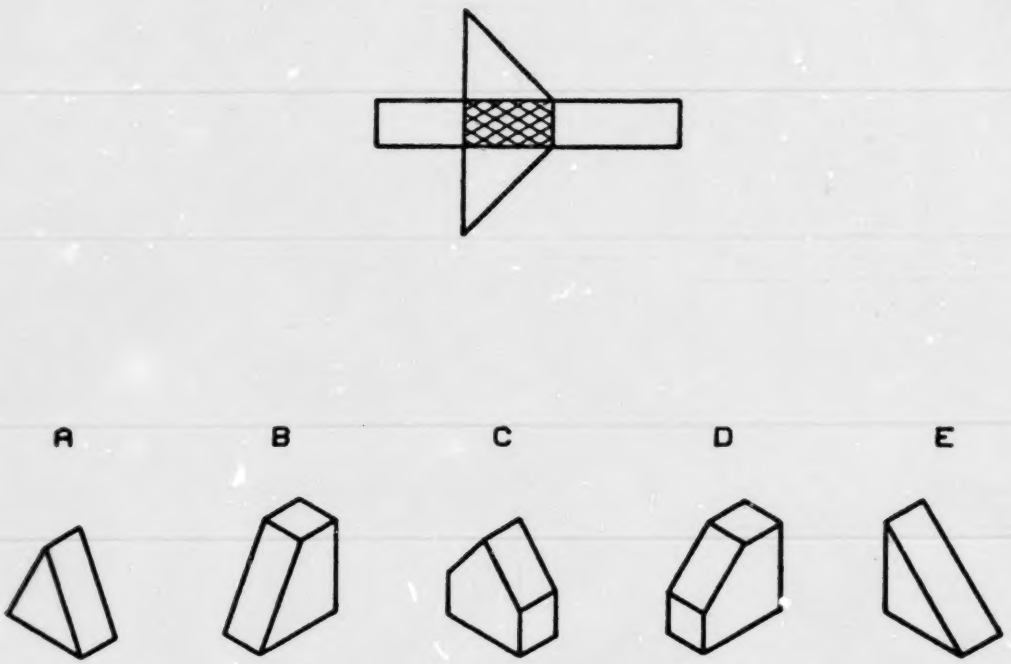

Figure 1. Illustration of a PSVT Development Item

The respondents are directed to (1) picture in their mind what the development looks like when folded into a three-dimensional object and (2) select from among the five objects (A through E) the one that looks like the folded development. The correct answer for this example is E.

Figure 2 shows a PSVT Rotation item. For this type of item the respondents are directed to (1) study how the object in the top line of the question is rotated; (2) picture in their mind what the object shown in the middle line of the question looks like when rotated in exactly the same manner; and (3) select from among the five drawings

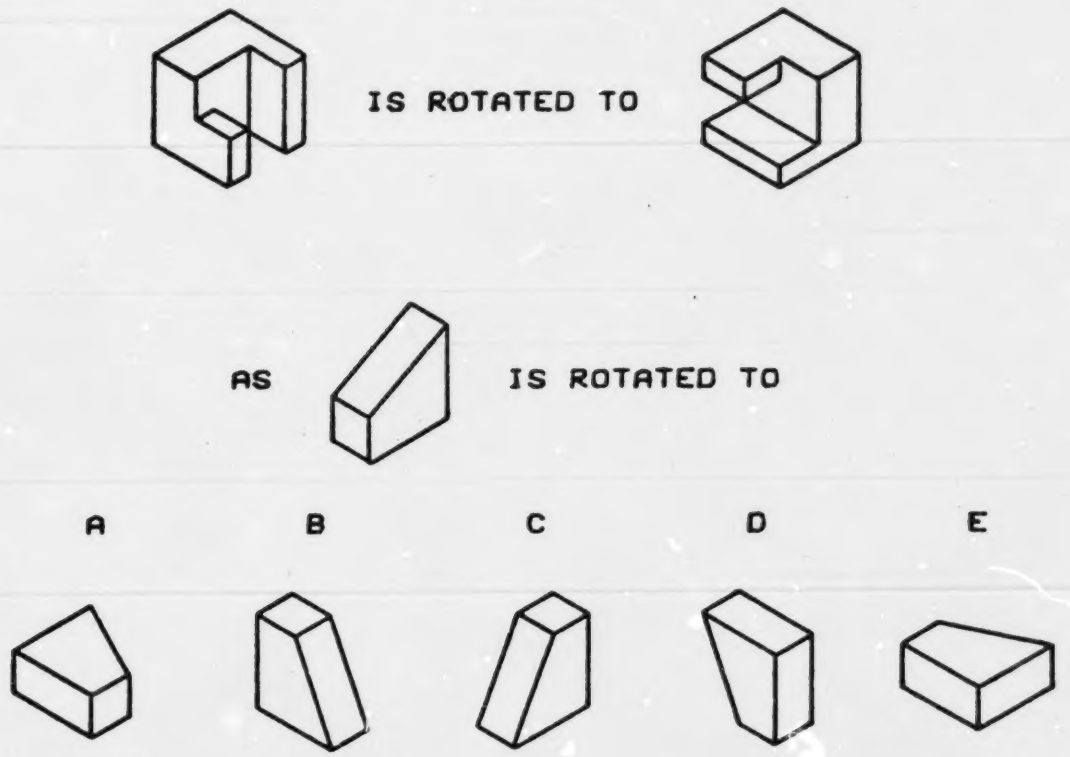

Figure 2. Illustration of a PSVT Rotation Item

(A through E) the one that looks like the object rotated in the correct position. The correct answer for this example is B.

Figure 3 shows a PSVT View item. Presented in the item is an object positioned in the middle of a "glass box" and five drawings representing what the same object looks like when seen from different viewing positions. The black dot in the bottom right corner of the "glass box" identifies the desired viewing position. The respondents are directed to

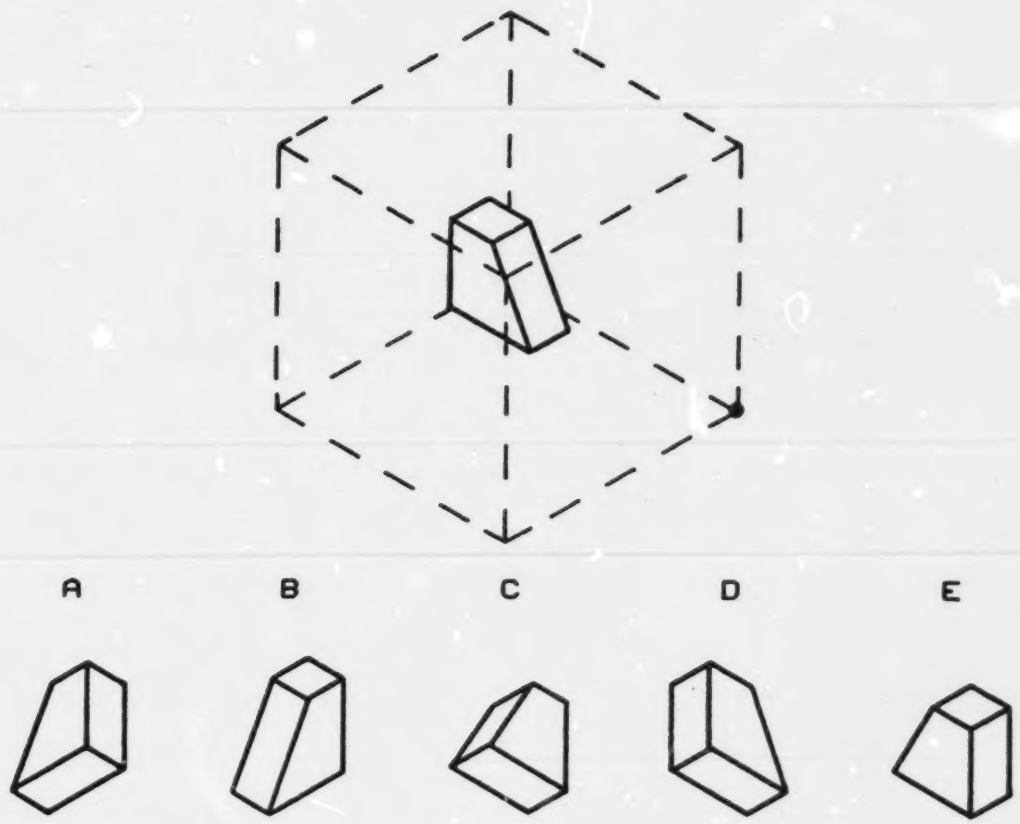

Figure 3. Illustration of a PSVT View Item

(1) imagine themselves moving around the "glass box" until the black dot is located directly between them and the object; (2) picture in their mind what the object in the "glass box" looks like from this viewing position; and (3) select from among the five drawings (A through E) the one that looks like the object as seen from the viewing position. The correct answer for this example is C.

The PSVT yields four separate measures of spatial test performance: indices of performance on each of the three subtests and a composite index of overall spatial test performance. The reliability of the subindices and the composite index was estimated using the Kuder-Richardson Formula 20 procedure. Internal consistency reliability coefficients ranging between .65 and .87 were observed for the subtests and .92 for the total test. Since the comparisons of interests were between groups of subjects rather than between individuals, these observed coefficients were considered more than adequate.

Sex, handedness, and birth order information was collected on all subjects using a questionnaire. This questionnaire was included within the PSVT.

Experiential background information was collected on a sample of 80 of the 217 subjects participating in this study using the new Spatial Experience Questionnaire (SEQ) (McDaniel, Guay, Ball, & Kolloff, 1978). The SEQ lists 25 activities that were identified by a panel of judges as experiences most likely to contribute to the spatial development of individuals (e.g., playing chess and drawing). The 25 activities were classified as being either female sex-typed, male sex-typed, or common to both sexes. The SEQ contains an equal number of female and male sex-typed activities. On the SEQ the respondents provided two kinds

of information for each of the 25 activities listed: the extent of their participation (i.e., very often, often, occasionally, and never) and the extent of their enjoyment (i.e., very much, much, little, and none).

The SEQ yields three separate measures of spatial experience: a participation score, an enjoyment score, and a composite score. In order to determine which score was most highly related to spatial performance, Pearson product-moment correlation coefficients were computed between all possible pairs of PSVT and SEQ measures. The SEQ participation score was found to be most highly correlated with spatial performance; therefore, SEQ participation was selected as the measure of experience for this study.

From the information collected, the 217 subjects were classified according to the independent variables of sex, handedness, and birth order. Eighty of the 217 subjects were further classified according to the independent variable of spatial experience. These 80 subjects were divided at the median of the distribution of SEQ participation scores into a high and a low spatial experience group of 40 subjects each.

Results

Factorial analysis of variance procedures were used to test the research hypotheses relating to the main and interaction effects of sex, handedness, birth order, and spatial

experience. Separate analyses of variance were run for each of the four indices (i.e., dependent variables) of spatial performance provided by the PSVT. Appropriate probing techniques were employed when significant results were observed.

Although none of the analyses revealed significant interaction effects, significant main effects of the individual factors were found. Significant sex main effects were found for the development subtest scores F (1,211) = 20.96, $p < .01$; rotation subtest scores F (1,211) = 44.48, $p < .01$; view subtest scores F (1,211) = 38.94, $p < .01$; overall PSVT scores F (1,211) = 49.29, $p < .01$. T-tests were run to probe the sex main effect for the four dependent variables. For all four measures of spatial performance, the data revealed that the group of males scored significantly higher ($p < .01$) than the group of females. The mean scores by females and males on the four measures of spatial performance are presented in Table 1.

Table 1

Mean Scores by Females and Males

on Four Measures of Spatial Test Performance

	Development Subtest	Rotation Subtest	View Subtest	Total PSVT
Female	7.88	5.96	6.62	20.55
Male	9.67	8.55	9.26	27.45

No significant handedness main effects were found at the .05 level. However, the data revealed that the group of dextrals scored consistently higher than the group of sinistrals on all four spatial performance measures. For the development subtest scores, the mean for the dextrals (8.67) was significantly higher than the mean for the sinistrals (7.87) at the .10 level, t (215) = 1.46.

A significant birth order main effect was found for the rotation subtest scores F (2,214) = 3.79, $p < .05$, but not for the other three measures of spatial performance. A Newman-Keuls probe of the birth order main effect revealed that the mean rotation score of 7.61 for the group of subjects who were neither first- nor lastborn was significantly higher ($p < .05$) than the mean of 6.45 and 6.72 observed for the group of firstborns and lastborns, respectively. It should be noted that for this analysis the only children were classified as firstborns, since their small number made it impractical to place them in a separate grouping.

A significant experience main effect was found for the rotation subtest scores F (1,50) = 7.24, $p < .01$, but not for the other measures of spatial performance. A t-test was run to probe the experience main effect. The t-test revealed that the mean rotation score of 8.51 for the subjects classified in the high spatial experience group was significantly higher ($p < .01$) than the mean score of 6.68 observed for the subjects classified in the low spatial experience group.

Conclusions/Discussion

The results provide support for the literature suggesting that sex, birth order, and experience are factors affecting spatial test performance. For sex, the data indicates that among university students males perform significantly better than females on spatial tests. This observation is consistent with literature reviews (e.g., Maccoby & Jacklin, 1974) indicating sex differences favoring males. For birth order, the data indicates that university students who were born neither first nor last in their family perform significantly better on some types of spatial tests than university students who were born either first or last in their family. This result is consistent with the conclusion of Kinsolving and Bone (1971) and Sherman (1974) that birth order has a significant effect on performance, but inconsistent with their finding that the effect interacts with sex, i.e., firstborn males perform better than firstborn females. For experience, the data indicates that university students who have often participated in activities requiring spatial thinking perform significantly better on some types of spatial tests than university students who have seldom participated in these same activities. This observation is consistent with studies (e.g., McDaniel, Guay, Ball, & Kolloff, 1978) indicating positive effects of selected experiences on spatial performance.

The birth order finding was relatively surprising. However, there are several plausible explanations for the observed birth order differences favoring people who were neither first- nor lastborns in their family. For example, these middleborn people are generally found to be less protected from their environments than first- or lastborns. The extra opportunity to interact with the environment may provide these people with additional experiences necessary for the development of higher-order spatial operations.

The results of this study provide little support for the literature (e.g., Yen, 1975) suggesting that handedness is related to spatial test performance. The literature suggests that dextrals perform better than sinistrals, and that handedness interacts with sex. The data indicates no support for the interaction notion, but shows consistent handedness differences favoring dextrals. Although the directions of the differences are consistent with the literature, they were not found to be significant at the .05 level.

The findings provide substantial support for the notion that a factor may have different effects for different types of spatial processing. For the factors of birth order and experience, significant results were found for the rotation subtest scores, but not for the other measures of spatial performance. In fact, none of the statistics for the other subtest scores were even close to significance at the .05

level. The point that the significant results were found for only the rotation subtest scores is not surprising. As was reported earlier, this subtest has been found by Guay, McDaniel, and Angelo (1978) to elicit significantly more gestalt type processing than the other subtests. The authors suggest that the type of task included on the rotation subtest has the most potential for measuring true spatial ability as defined in the literature.

The results of this study provide no support for the notion that individual differences in spatial test performance may be explained by the interaction of the four factors investigated. Although the literature (e.g., Sherman, 1974; Yen, 1975) reported some significant interactions, no significant interaction effects of the factors were observed in this study. It appears that the factors of sex, handedness, birth order, and experience work independently in affecting spatial test performance.

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